Diffraction:

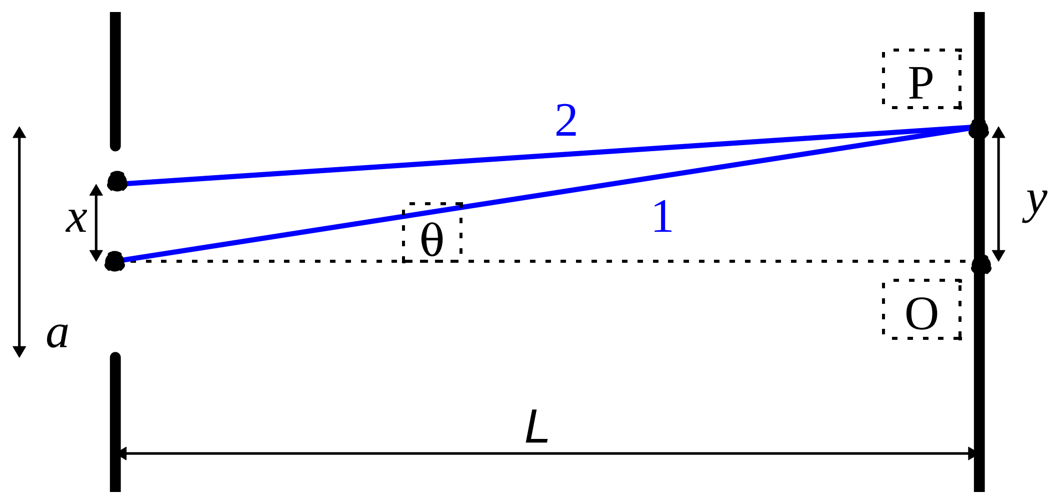
Diffraction is the divergence of light from its initial line of travel.

Diffraction from a **single slit** (Fraunhofer diffraction):
1) Central maximum, with maxima and minima on each side.
2) Dark and bright fringes on each side.

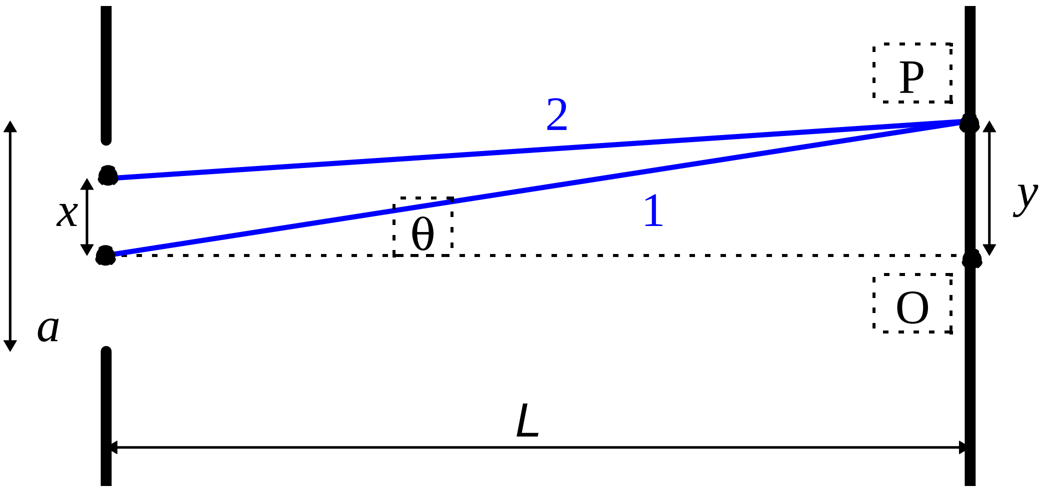
Destructive interference (a dark fringe) occurs if

$$\boxed{y/L = \sin\theta = m\lambda/a}$$

where $m = \pm 1, \pm 2, \pm 3$, etc.
(assuming y, x, $a \ll L$)



Intensity of the single-slit pattern



The path difference between the rays 1 and 2 is

$$\Delta r = \sqrt{L^2 + y^2} - \sqrt{L^2 + (x-y)^2} = L\sqrt{1+\left(y/L\right)^2} - L\sqrt{1+\left(x-y/L\right)^2} \approx$$

$$\approx L\left[1+\frac{1}{2}\left(y/L\right)^2\right] - L\left[1+\frac{1}{2}\left(x-y/L\right)^2\right] \approx \frac{xy}{L} = x\sin J\,,$$

where we have expanded the square root $\sqrt{1+e} = 1 + e/2$ and kept only linear terms in x/L.

This path difference leads to a phase difference $\Delta j = kx\sin J$.

The (horizontal component of the) electric field at point P due to ray 1 is $E_P(x) = E_0\cos(\Delta j)$. According to the superposition principle, we need to add the electric fields of all rays that come from the slit, i.e.,

$$E_P = \int_{-a/2}^{a/2} dxE_0\cos(kx\sin J) = \frac{E_0}{k\sin J}\sin(kx\sin J)\Big|_{-a/2}^{a/2} =$$

$$= \frac{2E_0}{k\sin J}\sin\left(\frac{ka\sin J}{2}\right).$$

This gives us the total electric field at point P.

The intensity is proportional to the square of the electric field.

$$I_P \propto E_P^2 \propto \left(\frac{2E_0}{k\sin J}\right)^2 \sin^2\left(\frac{ka\sin J}{2}\right).$$ Therefore,

$$\mathrm{I}_J = I_0\left[\frac{\sin\left({}^{b}\!/_{2}\right)}{{}^{b}\!/_{2}}\right]^2, \quad \text{where} \quad b = ka\sin J = \frac{2pa}{l}\sin J.$$

Diffraction Grating:

A **diffraction grating** consists of many slits with slit spacing *d*. According to Huygen's principle, each slit produces a wavelet (diffraction). The wavelets produce an interference pattern.

For **maximum intensity** of the diffracted light (constructive interference), the waves from all slits need to be in phase.

Therefore, the condition for a **maximum** is

$$\boxed{\mathbf{d\sin\theta = m\lambda,}}$$

where *m* is an integer. We will observe a zero-order maximum in the center and a series of maxima and minima on each side.

Application: Monochromators or Spectrometers produce monochromatic light by selecting a single wavelength out of a continuum of wavelengths.

Resolving Power of a Diffraction Grating:

The resolving power of a grating or prism tells us if two nearly equal wavelengths λ_1 and λ_2 can be distinguished (resolved).

The needed resolving power is $R = \frac{l}{|l_1 - l_2|} = \frac{l}{\Delta l}$.

For a diffraction grating, the resolving power in m-th order is $R=Nm$, where N is the number of grooves in the grating illuminated by the light source.

<u>Polarized Light:</u>

If an EM wave is travelling along the *z*-axis, then the electric field vector can either point along the *x*- or *y*-axis. (The magnetic field vector is fixed, once the direction of the electric field is known.) The direction of the electric field vector is called the **<u>plane of polarization</u>**.

Normally, light is **<u>unpolarized.</u>** The electric field is oriented randomly in the *xy*-plane, i.e., many different EM waves with different polarizations contribute to naturally occuring light.

Polarized light can be produced in three different ways:

<u>Polarization by absorption:</u>

A polarizer has a **transmission axis**. Light polarized along this axis is transmitted, light polarized perpendicular to this axis is rejected.

If unpolarized light hits the polarizer, 50% of the intensity is transmitted. If polarized light hits the polarizer and the angle between the direction of polarization of the incident beam and the axis of transmission is θ, then the transmitted intensity is $\mathbf{I=I_0\cos^2\theta}$.

<u>Polarization by reflection:</u>

At the Brewster angle θ_P, the reflected beam is polarized in the plane of incidence (p-polarized) and the refracted beam is polarized perpendicular to the plane of incidence (s-polarized). The **plane of incidence** is formed by the incident beam and the surface normal. The **Brewster angle** is given by $\mathbf{\tan\theta_P}=n$.

<u>Polarization by scattering:</u>

See Figure 28.26 in Serway’s book.